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Report of the first session of the

WORKING PARTY ON ACOUSTIC METHODS FOR FISH DETECTION AND ABUNDANCE ESTIMATION of the General Fisheries Council for the Mediterranean (GFCM)

Ancona, Italy, 12-16 November 1979

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN

REPORT OF THE FIRST SESSION OF THE WORKING PARTY ON ACOUSTIC METHODS FOR FISH DETECTION AND ABUNDANCE ESTIMATION

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Rome 1980

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I. INTRODUCTION

1. The first session of the GFCM Working Party on Acoustic Methods for Fish Detection and Abundance Estimation was held in the Laboratory for Fisheries Technology at Ancona from 12 to 16 November 1979 at the kind invitation of the Italian Government.

2. The participants (see Annex B) were welcomed by the Director of the Laboratory, Mr. Bombace, who also outlined the history of the formation of the Working Party and advantages and limitations of acoustic methods. He pointed out that several countries in the GFCM area were hoping to obtain at least a rough estimate of the standing stocks of pelagic resources in their waters. He added that the Laboratory at Ancona had put a lot of funds and effort in improving its acoustic capabilities and that interesting results had already been obtained.

3. Mr. S.C. Venema, Technical Secretary of the Working Party thanked the Italian Government and Mr. G. Bombace and his staff for hosting this meeting, sharing the regret that not all the nominated members of the Working Party could attend, and pointed out the wide scope of the subjects to be covered during such a short meeting (the Agenda is given in Annex A).

4. A warm welcome was also given by Mr. G. Cingolani, Director of the Fisherman's Cooperative in Ancona, who stressed the importance of international cooperation both in fishing and in the management of shared stocks. He terminated his address by inviting the participants to visit the new fish processing plant in Ancona the next day.

5. The meeting was adjourned for a visit to the research vessel SALVATORE LO BIANCO where Messrs. Azzali and Luna demonstrated the acoustic data processing and navigational equipment installed on board. A short visit was subsequently made to the Laboratory.

6. In a general introduction by Mr. Venema, the following important points for discussion were underlined:

(a) The need for elimination of subjective judgements of the integrator readings and echosounder recordings, for example, by applying a more intense sampling programme.

(b) The importance of critical analysis of the live fish calibration and the subsequent calculation of the constant C.

(c) The need for careful reporting of the results, in a scientific manner, including the determination of variance of the estimates.

7. Subsequently, a long-term programme of work for the Working Party was introduced by Mr. M. Azzali, Convener of the Working Party, and adopted (see Annex C).

8. Mr. D. Levi was appointed Rapporteur, and Mr. P. Oliver Co-Rapporteur.

II. CALIBRATION

A. Electronic Calibration

9. Mr. Azzali introduced the problem of calibration, and the various measurements to be made during electronic calibration. The use of reference targets and calibration by hydrophones was discussed by the group in some detail.

10. It was noted that there are two methods of determining the echosounder constant: the hydrophone and the standard target method. They are practically independent, and both have limitations and merits.

11. The advantage of a standard target over a measuring hydrophone is that it is sufficient to determine its target strength only once while a hydrophone requires to be calibrated periodically.

12. The advantage of a measuring hydrophone over a standard target is the possibility of determining the acoustic parameters (SL and VR) which can be compared with certificate data, given by the supplier. The accuracy of adjusting the Standard Target to the acoustic axis of transducer is conditioned by the same factors as when a hydrophone is used.

13. It was noted that the sphere with a diameter of 6 cm is not of the optimum size for frequency generated by a 38 kHz echosounder. Therefore, if the same standard target has still to be used, it is always necessary to keep the working frequency of the echosounder under control. It was also found desirable that the measurements of the back scattering cross sections are made available at the frequency range most likely generated by a 38 kHz echosounder. Mr. Brede informed the Working Party that the problem is under study at SIMRAD.

14. Care should also be taken to check the distance between transducer and standard target to make sure that the target is within the operating range of the TVG and that the amplitude of the echo signal of the sphere falls within the most suitable part of the echosounder's dynamic range. Some of the conclusions of the discussions are presented below.

15. In conclusion of its discussion on this item, the Working Party adopted the following recommendation:

> Recognizing the need for a good electrical calibration of the acoustic system, the first session of the Working Party on Acoustic Methods for Fish Detection and Abundance Estimation
>
> recommends that all measurements are executed as listed in Burczynski (1979) and SIMRAD's specifications for echosounder and echo-integrator; in addition, that measurements on the pulse repetition rate and the dynamic range of the echo-integrator and echosounder be made, and that the TVG function be checked as described by Craig (1973);
>
> further recommends to determine the constant of the echo-integrator at different gain settings for the two channels by feeding the echo-integrator input with a certain voltage provided by an external measuring generator.
>
> The Working Party also recommends to use a steel sphere of 6 cm diameter (specification SIMRAD) for calibration and intercalibration for echosounders with frequencies of 70 and 120 kHz.
>
> (N.B. The result of investigations to determine a good size standard target for low frequency echosounders (e.g., 38 kHz) is awaited from SIMRAD.)

B. Directivity Function

16. In the formula currently in use to describe the directivity function for echo-integrators, the integral directivity function (Ψ) is the substitution of the value of the true insonified volume of the space directivity diagram with the equivalent ideal beam pattern (Bodholt, 1977; Urick, 1975). However, recent analyses show that such a substitution is incorrect and that it may lead to errors in determining fish concentration density (Yudanov et al., 1979).

17. It was suggested to treat the angular coordinates of beam directivity function as random variables; it follows that a joint probability density function must be introduced. In considering the above problem, the Working Party established to keep the directivity effect under active investigation.

C. Live Fish Calibration

18. Mr. Venema introduced the subject giving an outline of the number of different setups currently in use.

19. Mr. Azzali reported a comparative experiment using different shapes of cages, whereby the elliptic-like shape came out to fit best the theoretical relationship between fish density at low levels and echo-integrator output. The explanation probably lies in the correspondence between the shapes of the beam and of the cage.

20. Other problems of calibration with live fish were debated, to some extent, relative to:

(i) Optimal range of densities in the calibration cage.

(ii) The quality of the experimental procedure, with particular reference to the number of replications under a wide enough range of fish densities, in day and night conditions and the depth at which the experiment is conducted.

(iii) The advisability of verifying the calibration constant obtained with the net cage method by the $\overline{TS}$ to $\overline{L}$ regression method, using the following formulae:

$$C = 3430\ \overline{W}\ C_{ES}\ C_{EI}\ C_F$$

where:

$\overline{W}$ = average weight of fish [g]

C_{ES} = constant related to echosounder = $10^{0.1C_1}$; C_1 is the "SIMRAD" constant [dB]

C_{EI} = constant related to echo-integrator = $10^{0.1(V_{01}-A)}$; V_{01} is the normalized value of an average VL, corresponding to the echo-integrator unit deflection (ex: M = 1 mm; ΔR = 1 m; V_{01} = -2dB); A is the echo-integrator gain [dB]

C_F = fish constant = $10^{-0.1(m \log \overline{L} + b)}$; $m \log \overline{L} + b = \overline{TS}$ regression line equation

21. The intercalibration among vessels and between external and hull-mounted transducers was also brought up and four possible methods were suggested:

(i) Using a standard target

(ii) Integrating a smooth bottom with drifting vessel

(iii) Integrating in the same layer of fish

(iv) Using C_I.

22. Since the alignment of a standard target is rather difficult in the field, the use of bottom integration was particularly recommended for its simplicity but care should be taken not to saturate the system. The two transducers must be at the same depth and the same bandwidth should be used.

D. Packing Density of Schools

23. Mr. G. Bazigos explained the results of recent studies on packing densities of fish schools based on published studies where minimal distances in the formation pattern between fish in schools are given. Bazigos and Rijavec (in press) developed, for some species of small pelagic fish, tolerance limits and established maximum and minimum packing densities in terms of kg of fish/m^3, and number of fish/m^3. These tolerance curves were used to check empirical values of school sizes found on visual observations. It was also found that in certain live fish calibration experiments fish concentrations were used that were much higher than the established maximum tolerance limit. Such experiments should therefore be scrutinized and the level of validity of the estimated C values (acoustic constant) be reconsidered. Another point that was brought up about the validity of the results of such experiments was the influence the location a cluster of points on the regression plane had on the level of accuracy of the estimated regression line on which the C is based.

24. The tolerance limits for Mediterranean species should be calculated and published, so as to avoid bias traces in calibration experiments.

E. Guidelines for Calibration Experiments

25. The Working Party, while discussing the live fish calibration experiments in great detail, came up with several suggestions for improvement of these important experiments. In addition to the description given by Burczynski (1979), the following suggestions were made:

(i) Try to exclude as much as possible any echo from the cage, by designing the cage in such a way that neither the rings nor the net of the side of the case are covered by the beam.

(ii) The experiment should preferably be conducted with the same pulse length as is used for the survey, to avoid conversion factors. Same problems related to the size of the cage (approximately five times the pulse length) and saturation due to the higher power should be studied.

(iii) The TVG function should be carefully controlled and the cage put in such a way that it falls within the TVG's operating range (approximately 5 m in most cases).

(iv) There are indications that better results, especially at low densities, were obtained in cases where an ellipsoid cage was used with a rectangular transducer. In other words, it seems advantageous to adjust the shape of the cage to the shape of the beam of the transducer.

(v) The packing densities of fish species used in calibration experiments must be within the tolerance limits observed in natural environments (Bazigos and Rijavec, in press).

It was observed that the use of arbitrary packing densities in calibration experiments might introduce bias in the calculated calibration coefficients which, in turn, effects the accuracy of the calculated (estimated) overall biomass.

It was suggested that more work be conducted in this respect aiming at the calculation of tolerance limits of packing densities for important fish species.

(vi) The fish should be well acclimatized before experiments are conducted; preferably fish should be kept in a keep net or tank for 24-48 hours prior to being transferred to the cage and another 24 hours in the cage prior to the start of the measurements.

(vii) The location for the experiments should be well chosen. It should be a place with a minimum of current, ambient noise and wave action and be of a considerable depth. The water temperature, turbulence and oxygen content should be checked regularly, as well as the formation of air bubbles on the cage, transducer and other parts.

(viii) It was suggested to use two standard targets (or hydrophones) located on the acoustic axis, respectively above and under the cage. The function of the standard target located above the cage was to provide rapid means of verifying the alignment of the cage and the functioning of the echosounder, while the function of the one under the cage was to examine the characteristics of the pulse after it has passed through the fish aggregation.

(ix) It was considered desirable to use two synchronized cameras located respectively at the side of the net cage and on the oscilloscope screen. The function of these two cameras is to correlate periodically the photographs of fish in the cage and the echo envelope.

III. ECHO IDENTIFICATION

A. Echogram Classification

26. Mr. Azzali presented the classification system presently used in Ancona. After a first distinction between 'dispersed', 'accumulation' and 'schools' (further distinguished as localized or scattered according to their extension) (Azzali, 1979), further classification is made on the schools, coding them according to their shape on the paper:

(1) Grain or nail
(2) Hyperbole
(3) Plume
(4) Cloud
(5) Mountain or tower
(6) Layer

27. Mr. Azzali also stressed the importance of making use of this or some other form of classification and the possibilities of relating the shapes to environmental characteristics and distributional patterns as reported by fishermen, in order to gain information useful for species identification.

28. Echogram interpretation was also judged a useful source of information for fishermen when only an echosounder is used for surveys.

29. Some interesting perspectives along these lines were also put forward concerning the use of a computer for echogram classifications and analysis of the echo envelope for each pulse as an aid to species identification.

B. Identification through Fishing

30. Mr. M. Ferretti explained the development of pelagic trawls, which can be towed, even close to the bottom, at high speed (5-6 knots) so as to reduce the escapement of fast-swimming species. Net designs are attached (Annex D). It was underlined that the size of the meshes in the cod end should not exceed 10 mm stretched, to avoid gilling of anchovies.

31. Mr. Oliver also reported on a net being constructed in Vigo (Spain), with a theoretical opening of 15 x 15 m and an experimental vertical opening of about 12 m at a towing speed of 5 knots. Some discussion also took place about difficulties in conducting test-trawling in shallow waters, especially when using single-boat towed nets.

C. Integram Interpretation

32. The technique described by Nakken and Dommasnes (1975) to discriminate among species, when their different Cs are known and species composition has been determined on the basis of net samples and/or identification from the echograms, was illustrated by Mr. Azzali.

33. It was also pointed out that interpretation of echosurvey results could be much helped in the future by a further breakdown of M into layers, which is possible with a digital integrator.

IV. SURVEY DESIGN AND STRATEGY

A. Survey Design

34. Mr. Bazigos introduced this very important item. He pointed out that one of the main problems in acoustic survey systems is to determine the accuracy of the results of the surveys (echosurveys and sonar); a block diagram was distributed to illustrate the complete spectrum of sampling and non-sampling errors inherent in acoustic survey systems (see Annex E).

35. It was strongly pointed out that the general presentation of the point estimates of the surveyed magnitudes on an individual survey basis are of very limited use, and that long-term programmes should be designed and executed in order to make full use of the different kinds of information that such programme can provide, i.e.:

(i) estimates of absolute biomass over time and with a given level of precision of the estimates,

(ii) some estimates of potential yields,

(iii) spatial and temporal distribution of the surveyed stocks, and their availability to the fisheries,

(iv) aggregation patterns and migration routes, etc.

However, it was regretted that, in practice, only a small portion of the information provided by acoustic surveys is actually used.

36. Mr. Bazigos stressed that, for management purposes, biomass point estimates must be given with their limits of confidence, and that only a probabilistic approach in the planning and execution of acoustic survey programmes can provide the necessary basis for a proper calculation of the accuracy of the calculated estimates which, in turn, enables the spatial and temporal comparison of the obtained results.

37. A survey conducted off South-West India was then used as a case study to illustrate this approach. It was stressed that all supplementary information on fish distribution available (possibly from large-grid pilot surveys) should be taken into account to stratify the surveyable area accordingly, e.g., space (1° latitude) and depth (5 unequal depth strata) were adopted for South-West India.

38. A probabilistic approach involves that the information coming from one survey is used to plan the next, and that vice versa, the information coming from the second survey onwards should be matched with that of the preceding ones. A differentiation between first and successive surveys was thus introduced.

39. In the first survey a particularly "strong sampling" should be used, and all "elementary area cells", as defined through a priori stratification, should be covered imperatively. This, of course, implies prior knowledge of overall cost and time constraints.

40. Data from the first surveys should then be analysed to identify areas of higher densities where sampling in next surveys should be more intense, according to the predetermined survey design. Then, if during a cruise high densities are encountered, the intensity of the sample of the survey can be increased by decreasing the distance between the tracks (spacing interval), still maintaining the same pattern (which in any case should not be a zig-zag track), the size of the actual sample can be higher than the size of the preselected sample.

41. In defining the cruise track, the main migratory direction of the fish should be taken into account. In order to neutralize it, the direction in which the survey area is covered should be along and against the known direction of movement of fish.

42. The first year should also preferably be covered by as many surveys as possible to acquire knowledge of likely cycles in biomass fluctuations.

43. Net sampling (fishing) during an echosurvey should be regarded as a concurrent sub-sampling process, and in a probabilistic design, allocation of sub-samples should be predetermined too, just as with allocation of the main sample (i.e., tracks per cell).

44. Previous reckoning of course and time constraints is necessary to determine the maximum allowable number of units of the sub-samples (hauls). On the contrary, the execution of sub-sampling only in places where certain densities are met, would limit the overall utility of the results of the survey.

45. Mr. Azzali explained his different approach to net sampling, whereby he returns on the acoustic tracks covered during preceding days, allocating hauls according to the densities previously met (which are checked again by integrator). It was observed that such a technique is suitable for small areas and that it obviously doubles the sailing time.

46. The participants to the meeting agreed that it would be helpful if Mr. Bazigos could, in the future, examine and discuss echosurvey designs prepared by the various countries represented in the Working Party. Mr. Bazigos readily accepted this view and expressed his willingness to open such a cooperation.

B. Data Analysis

47. The analysis of survey data should be carried out on a "cell basis", giving an estimate of the size of the surveyed magnitude and its variance for each single cell and then combining them to get the overall estimate of the surveyed biomass and its variance (separation approach).

48. If an elementary cell has an area A_{ij} (e.g., i = 1° latitude, j = depth range), the total estimate of biomass in it would be:

$$\hat{X}_{ij} = A_{ij}\bar{C}\left(\frac{\Sigma_k x_{ijk}}{n_{ij}}\right) = A_{ij}\overline{Cx}_{ij}$$

where:

n_{ij} = total number of Elementary Distance Sampling Units (EDSU)

$\hat{\bar{C}}$ = the estimated average calibration constant, and

$\bar{x}_{ij} = \left(\frac{\Sigma_k x_{ijk}}{n_{ij}}\right)$ the average estimated echo-integrator reading per nautical mile (EDSU) within the given cell.

The estimated variance of $\bar{X}_{ij}$ being:

$$\hat{V}(\hat{X}_{ij}) = A_{ij}^2 \left[\bar{C}^2 \hat{V}C(\bar{x}_{ij}) + \bar{x}_{ij}^2 \hat{V}(\hat{\bar{C}}) - \hat{V}(\hat{\bar{C}}) \cdot \hat{V}(\bar{x}_{ij}) \right]$$

49. To increase the precision of the calculated estimates (minimizing variance), due to the high variability of the population and the high degree of auto-correlation in space of the population (i.e., the integrator readings of a particular elementary sampling unit is correlated up to the fifth order with the other nearest elementary sampling units), the so-called method of collapsed strata for estimation purposes (point estimates, variance) should be adopted. In the case of India, when plotting the calculated errors (as coefficients of variation) against the corresponding biomass estimates in the different domains defined by depth and space (the so-called errorgrams) it came out very clearly that the pattern of correlation of errors and densities was alike. Also, it was observed that the negative bionomial distribution can be used to describe the pattern of distribution of the surveyed populations.

50. Some important consequences on cruise planning stem from this non-random negative-bionomial distribution, leading to the already mentioned intensification of sampling effort of the surveys (decreasing the predetermined spacing interval between sample tracks) in higher fish density areas.

51. The day and night problem, as far as its influence on fish distribution patterns and biomass estimates is recognized, can also be treated as an analysis problem by post-statifying the data accordingly.

V. DATA PROCESSING

A. Data Recording

52. Concepts/definitions (of survey magnitudes and codification system) especially in relation to source documents should be defined and made as uniform as possible. Source documents, either from the sonar and/or echosounder surveys or from fishing, i.e., trawling or purse-seine surveys should be designed on an integrated basis.

53. To help discussion, some examples of forms for raw data were presented and commented upon (Bazigos and Rijavec, in press).

54. The need was recognized for:

(i) a common coding system (as far as possible)

(ii) the adoption of a list of "fields" in the working sheets being a "minimum data requirement" list and

(iii) a suitable design of log sheets for successive automatic treatment.

55. The consensus of the Working Party was that under similar terms of reference a consultant should be hired by FAO, and that the outcome should work as a reference point for all those involved in echosurveys worldwide.

B. Tabulation

56. Tabulation, both as mechanical detailed tables and as summary tables for spatial and temporal analysis of data, should be accompanied by a graphical presentation of results. Some very interesting examples of such documents prepared for the echosurveys of South-West

India were shown and explained (oblique projection diagrams indicating spatial distribution of biomass, polar diagrams indicating temporal availability of biomass and for the various depth domains).

C. Programming Used for Data Processing (i.e., Software)

57. It was noted that the switch from a census to a sampling survey design, by decreasing the amount of data to be processed, allows extended use of desk-top calculator and mini-computer systems with suitable programming memory capacity. Due to the variety of languages and specifications now on the market, it seems difficult to standardize the software for the processing of survey data, but it was suggested that interchange of flow-charting procedures should be a flexible enough tool to help programmers operating with different working facilities.

58. The view was also expressed that for experimental work, with its numbers of impredictable processing trials, mini-computers are a very useful tool, while big computers and terminal peripherals are best suited for routine consolidated processing procedures, even if sometimes of difficult access.

59. However, the use of an on-line mini-computer on board the research vessel for data-logging does not forbid subsequent transferring of data to a big computer for processing, as manual data input through terminal is just as necessary from log sheets as from mini-computer print-outs. (The same mini-computer can, of course, also be used in the office.)

D. On-Line Mini-Computer, Planned Analyses

60. Mr. Azzali briefly summarized the contents of his paper presented in July 1979 in Cambridge, U.S.A. (Azzali, 1979). The echo data processing system installed on board the R/V SALVATORE LO BIANCO is used in two ways:

(i) The first way is based on the classic instruments (analog echo-integrator, etc.) by which the information is acquired in a standard and in a non-standard way.

(a) By the standard method the average fish density referred to the unit depth is obtained by sampling the integrator output integrating over every nautical mile.

(b) In the non-standard method the vertical distribution of the biomass is obtained by the "thin depth layers technique" (Burczynski et al., 1977).

The integrator output sounding is sampled uniformly and processed when a school or relevant aggregation is found.

With the computer programme, a horizontal (alongship) and vertical (depth) histogram is calculated for every school on a basis of a grid consisting of 1 m depth and a distance of 1 ping.

(ii) The second way, based on non-standard instruments, is first to discriminate the single fish and schools, then to analyse each school taking into account its geometry, local density and echo envelope.

From the geometrical point of view, the school silhouette is represented by a matrix of ones (its boundary) and zeros in a discrete two-dimensional image plane (1 m depth and 1 ping distance). The approach to the school image classification is developing along the following lines:

(a) collect a number of significant images of school of different species

(b) use this information to attempt the classification of further schools with the help of Bayes decision rule.

The assumption is that the geometrical parameters of schools are typical for each species of Clupeids depending upon the atmospherical and oceanographic conditions.

The analysis of the school structures (packing density and some biophysical characteristics) is carried out by processing the echo envelope with the "Discrete Fourier Transformer Technique", first during the calibration on live fish, then during the survey. It is almost certain that for the described procedure of categorizing an echo by noting the energy at different frequencies, in the future an increase of the bandwidth of the echosounder will be needed.

E. Mathematical Models

61. Mr. Azzali summarized also the results of an original study (Azzali, 1978) based on topology. The statistics analysis of the data obtained in the acoustic surveys on sardine stocks in the Adriatic Sea (1976, 1977) suggested an original way to look at the biomass maps and the displacements of the stocks of pelagic fish and smaller seasonal movements. In this approach, the fish concentrations in the surveyed region are represented in a topological symbol, called "tree of the region". The centre of gravity of the region (the highest fish concentration) is called the "root of the tree". Based on this view, a number of vectors can be defined expressing either the difference between the measured biomass distribution and an ideal equilibrium biomass distribution (displacement) or the changes of biomass in a fixed sub-area over time (movement).

62. Since his study did not include concentrations found in neighbouring Yugoslavian waters, it was suggested to expand his tree by extrapolation and subsequent checks with reports from that area.

VI. THE USE OF BIOMASS ESTIMATES IN THE ESTIMATION OF STOCK POTENTIALS

63. Mr. S. Garcia introduced a paper originally prepared by Troadec (1978) for a training course on resource surveys. This was followed by discussions on the pros and cons of various types of surveys (e.g., eggs and larvae versus acoustic surveys). The conclusion of the discussions was that as many methods as feasible should be used to obtain information on the abundance and the population dynamics of the stocks. One of the advantages of an acoustic survey was that estimates could be obtained of the biomass of virgin stocks. Such data are not only useful to indicate development possibilities, but can also be used in stock assessment once the fishery has taken its toll.

64. The use and derivation of the so-called Gulland formula $Y_{max} = 0.5\ MB_0$ was discussed, as well as possible ways of improvement and ways of obtaining estimates of the natural mortality coefficient M. Reference was made to papers by Cadima (In FAO, 1976), Rikhter and Effanov (1976), the yield tables of Beverton and Holt (1966), Allen (1971) and Pauly (in press).

65. Rikhter and Effanov (1976) developed an empirical formula to determine M based on length data:

$$M = \frac{1.521}{t_{m50}^{0.720}} - 0.155, \text{ whereby}$$

the age is used at which half the stock has reached maturity ("age at massive maturation").

66. One particular problem was that in some areas the biomass fluctuates enormously due to migrations caused by environmental changes and perhaps also biological reasons (Bazigos and Rijavec, in preparation). In many cases, many surveys are needed to understand the phenomena. The calculation of "average biomass" is a problem in such cases, that should be studied with care, for example

$$\bar{B} = \frac{1}{12} \sum_{t=1}^{12} B_t$$

, where the average biomass is based on monthly estimates.

VII. COORDINATION OF SURVEYS IN THE GFCM AREA

67. A special meeting to discuss possible ways of scientific and technical cooperation was convened by Mr. Bombace. Mr. Bombace distinguished two types and three levels of cooperation, as follows:

Type 1 Collaboration between scientific institutes in the framework of agreements on technical and scientific cooperation (e.g., as between Italy and Yugoslavia)

Type 2 Collaboration between scientific institutes from different countries outside such a framework

From the practical point of view, depending on the level of experience and the availability of equipment, several possible types of collaboration can be envisaged:

Level 1 Exchange of information and data, outside official meetings

Level 2 Exchange of research workers and technicians to work together on specific problems

Level 3 A joint project, e.g., an acoustic survey in a certain region in which case there are two possible approaches:

(a) Each country covering its own waters using its own vessels, but with inter-calibration of equipment and standardizing methods

(b) A fully integrated programme with one or two vessels having full access to the total area. This level is the most useful, but it requires timely authorization of the Governments involved.

68. The meeting concluded with an agreement on two bilateral cooperation proposals:

(i) a type 2, level 2, cooperation between Italy and Greece, whereby a Greek scientist will participate in an echosurvey in Italian waters, on board an Italian R/V (as a first step for further cooperation) outside the framework of bilateral scientific and technical cooperation agreements between the two countries;

(ii) a type 1, level 3.a, cooperation between Italy and Yugoslavia, whereby after inter-calibration (for which permission should be provided in due time by the Yugoslavian authorities) and cruise programming, the Laboratory of Ancona should perform a survey in the Italian waters and the Laboratory of Split should do the same in Yugoslavian waters, each with their own research vessels. The results should then be processed jointly. That would be inside the existing bilateral scientific and

technical agreement between the Governments of Italy and Yugoslavia. It was also agreed that for further discussion along these lines, a meeting will be convened by the Split Institute of Oceanography and Fisheries[1].

69. Agreements on cooperation between Morocco and Spain were discussed on several occasions. Mr. M. Lamboeuf explained that after installation of all acoustic equipment and a shake-down cruise, the FAO/Norway and FAO/UNDP Projects in Morocco would be ready for training and exchange of experience. Plans for a joint survey with Spain were far advanced but still needed further clarification.

VIII. DATE AND PLACE OF NEXT SESSION

70. Participants found that the session had been useful, in particular because of the relatively large training component, in the form of introduction of topics new to most people concerned. A further conclusion was that standardization will not be easy, and that more specialized meetings will be needed to achieve this. It was suggested that a second session of the Working Party should be organized in two years time. An informal meeting could also take place during the Fifteenth Session of the GFCM, which will be held in Palma de Mallorca from 22 to 26 September 1980, if a sufficient number of members of the Working Party attend the Session.

IX. ADOPTION OF THE REPORT

71. The report was approved in draft form on 16 November 1979. It was left to the Secretariat to put it into final form.

1/ This meeting should not be confused with the meeting mentioned in para. 157 of FAO Fish. Rep., No. 204, Report of the Seventh Session of the Working Party on Resource Appraisal and Fishery Statistics (Rome, 30 January-3 February 1978) which will be a technical consultation on stock evaluation in the Adriatic

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Annex A

AGENDA

1. Opening of the session
2. Visit to R/V SALVATORE LO BIANCO and Laboratory
3. Introduction and discussion on work plans for the Working Party
4. Calibration (electronic, live fish, reference targets, target strength measurements)
5. Echo-identification (echogram classification and analysis, measuring echo-parameters by micro-processors)
6. Survey design and strategy
7. Data processing and interpretation (processing methods and mathematical models)
8. The use of biomass estimates in the estimation of stock potentials and levels of exploitation
9. Coordination of surveys in the GFCM area
10. Date and place of next session
11. Adoption of the Report

Annex B

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Annex C

SUGGESTED PROGRAMME OF WORK FOR THE WORKING PARTY
M. AZZALI

I. GOAL OF THE WORKING PARTY

The goal of this Working Party is to establish a clear definition of the methodology to be used by GFCM member countries for the estimation of pelagic fish population through acoustic methods. Its responsibility will evolve into several distinct activities:

1. To identify the units, symbols and definitions that are important in fishery acoustics. An agreed standardization of symbols will be beneficial to all readers of reports on acoustic surveys;

2. To define the important parameters for the fish searching instrument calibration, since calibration is an essential component of the measuring process;

3. To apply acoustics as a tool to study marine organisms. The most promising topics for acoustic research techniques include: groupings of marine organisms in time and space and behaviour, the classification and possible identification of shoals and the quantitative biomass estimation;

4. To explore the various models that could improve our understanding of the relationship between physical, chemical, biological and oceanographic features and the distribution of pelagic fish. The assistance that modellers can render to acoustic scientists includes: forecasting of temporal-spatial evolution of marine systems, survey design, strategy and frequency, statistical elaboration and interpretation of acoustic data. Such models should take into account the diurnal, seasonal and spatial variations of biomass, and should include the relevant data on nutrients, phytoplankton and zooplankton.

5. To identify the regions inside the GFCM area which should be surveyed.

II. PROGRAMME OF THE WORKING PARTY

The programme of the Working Party will contain:

- descriptions of the activities carried out and the extent of our present knowledge

- identification of the technological gaps in the different countries and provision of expertise in acoustic techniques

- drafting an outline for future research giving alternative approaches where applicable.

In order to delineate the areas of discussion and to plan future activities, the programme will be divided into two broad subjects:

(a) The first one will be centred mostly on the procedures to understand the properties of the echoes when the character of insonified population is known, i.e., calibration;

(b) the second one will deal with the inverse problem. In this approach, the Working Party will attempt to deduce from acoustic signals information on the character and distribution of unknown marine organisms, i.e., survey.

1. Calibration

The first topic to be considered by the Working Party will be the theoretical and experimental approach to the measurement of the hydroacoustic equipment constant C_I. The two main methods are based on using a standard target (a metal sphere) or a hydrophone. The specific objective of our discussion will be a comparative analysis of the two methods, related to the real conditions of measuring the performance of hydro-acoustic instruments and to comparing the results of hydro-acoustic surveys.

The second topic will be the calibration of hydro-acoustical instruments on live fish. At present, different methods of calibration are used:

(i) Calibration on Fish Concentrations

The hydro-acoustic instruments are calibrated by integrating echo-signals from a fish concentration of a known density. This density can be determined by one of the following methods:

- by counting fish on the echosounder
- by underwater photogrammetry of the concentration
- by observation from a submarine apparatus
- by forming an artificial fish concentration in a net cage.

(ii) Calibration by Trawl

It has been observed that values of integrated echoes from a layer of fish swept by a trawl and the corresponding catch are highly correlated, especially in a monospecies situation. If the efficiency of the trawl is known, it is possible to determine the total biomass of fish from the integrator value.

(iii) Calibration by Target Strength Measurement

When the relationship between the average target strength of a given fish species and its length and weight distribution is known, it is possible to estimate the calibration constant C; thus saving costly and time-consuming field operations.

The Working Party will be examining different methods of calibration on the same fish species and compare the results. In this way, the theory and methods applied for fish biomass estimates could be verified and revised where necessary.

2. Survey

The Working Party will be concerned with problems related to the methods of survey planning as well as echo-identification, data analysis and processing. In order to solve these problems, it has been observed that there is a need for information on physical, chemical and biological processes regarding the surveyed region. Moreover, most of the acoustic information must be processed in a probabilistic rather than in a deterministic mode. Therefore, the approach of the survey falls into two separate categories:

- deterministic descriptions of the acoustic signals;
- probabilistic descriptions of marine systems, using acoustic and possibly physical, chemical and biological data.

Hence, the assistance which mathematicians, oceanographers and biologists can render to acousticians in this context is important.

Assessment of the interrelationships between these disciplines may form part of future activities of the Working Party.

Discussions within the survey context will be centred on the following topics:

(i) Echo Identification

First of all, the recordings of acoustic instruments, echosounder, echo-integrator and sonar, must be analysed in order to discriminate which part of an echo-signal is attributable to fish and which to noise. Moreover, it is necessary to classify the types of recordings in order to distinguish species and to gain information on movements of marine organisms in time and space.

(ii) Net Sample

Nets will continue to be used for capturing marine organisms to meet a variety of requirements including the verification of acoustic assessments and species identification. However, a number of questions must be solved:

- what is the optimum net?

- how can an echo trace of fish be sampled by net with complete accuracy?

- what proportion of fish of different species or sizes is caught by the net?

(iii) Survey Design and Strategy

With rare exceptions, no rationale is given in the literature for the selection of particular survey track designs. Although some complicated patterns are used in some acoustic surveys, in most cases assessment surveys of fish abundance have used either zig-zag or parallel transects. The crucial questions are:

- what is the optimum survey pattern for particular areas and species?

- what is the optimum space interval between transects?

(iv) Data Processing and Interpretation

Various theories have been developed relating to acoustic data processing in order to estimate the distribution by species of pelagic resources, their abundance and fluctuations in abundance and their optimum yield.

The problem is that the results obtained by different research workers are often not directly comparable. This is complicated by the fact that little exchange of data and results has taken place between research workers. Therefore, the discussion will centre on the following question: How should the survey data be processed in order to obtain the most reliable estimates? In our opinion, the answer to the above question requires an interrelation approach to the problem in order that acoustical, biological, chemical and physical data are taken into account.

III. POTENTIAL FUTURE APPLICATION OF ACOUSTICS

In considering the problems listed above, it must be remembered that existing acoustic equipment does not allow to differentiate between species and sizes.

The rapid development of digital techniques has brought the possibility of using them to:

(a) extract from the echo envelope statistical parameters, which correspond with biophysical characteristics of known individuals of a species,

(b) analyse on the basis of image classification a number of geometric parameters of schools of different species, which can be used to attempt the classification of further schools.

The first step of this process must be the A/D envelope conversion.

The second task is to select a set of statistical and geometric parameters which characterize the species under investigation.

In practice, this selection of distinguishing features is a very difficult process, but it could theoretically make it possible to exploit the resources more selectively, which is especially important in multispecies fisheries.

Extraction of distinct parameters by signal envelope analysis and image classification is the basic problem of future acoustics and it will become particularly important in the automatic hydroacoustic stock assessment systems.

Until now, trials of species identification have been made on the basis of subjective estimates of the echo sounder records and sample hauls; but these methods are imprecise and costly.

In the future, the Working Party may wish to address itself also to this area of research.

IV. CONCLUSION

Many survey operations have been completed in the GFCM area, and a large amount of data is available. Other surveys will be carried out in the future. The task of the Working Party is to standardize the methodologies of calibration and survey, i.e., standard notation and units, standard methodologies of calibration, survey design and data collection. Data from different surveys and areas would then be comparable.

The potential uses of survey data are manifold and involve a variety of disciplines. They include:

1. Stock management strategies

2. Relative and absolute estimates of population biomass and variability over time of the population as a whole, of any sub-population or of age/length classes

3. Geographical distribution and its variability over time of the population as a whole, of any sub-population or of age/length classes

4. Depth distribution

5. Comparisons with oceanographic data

6. Comparisons with biological data (plankton, spawning)

7. Comparisons with non-acoustic surveys

8. Comparisons with research on other species (prey, predators, food chains)

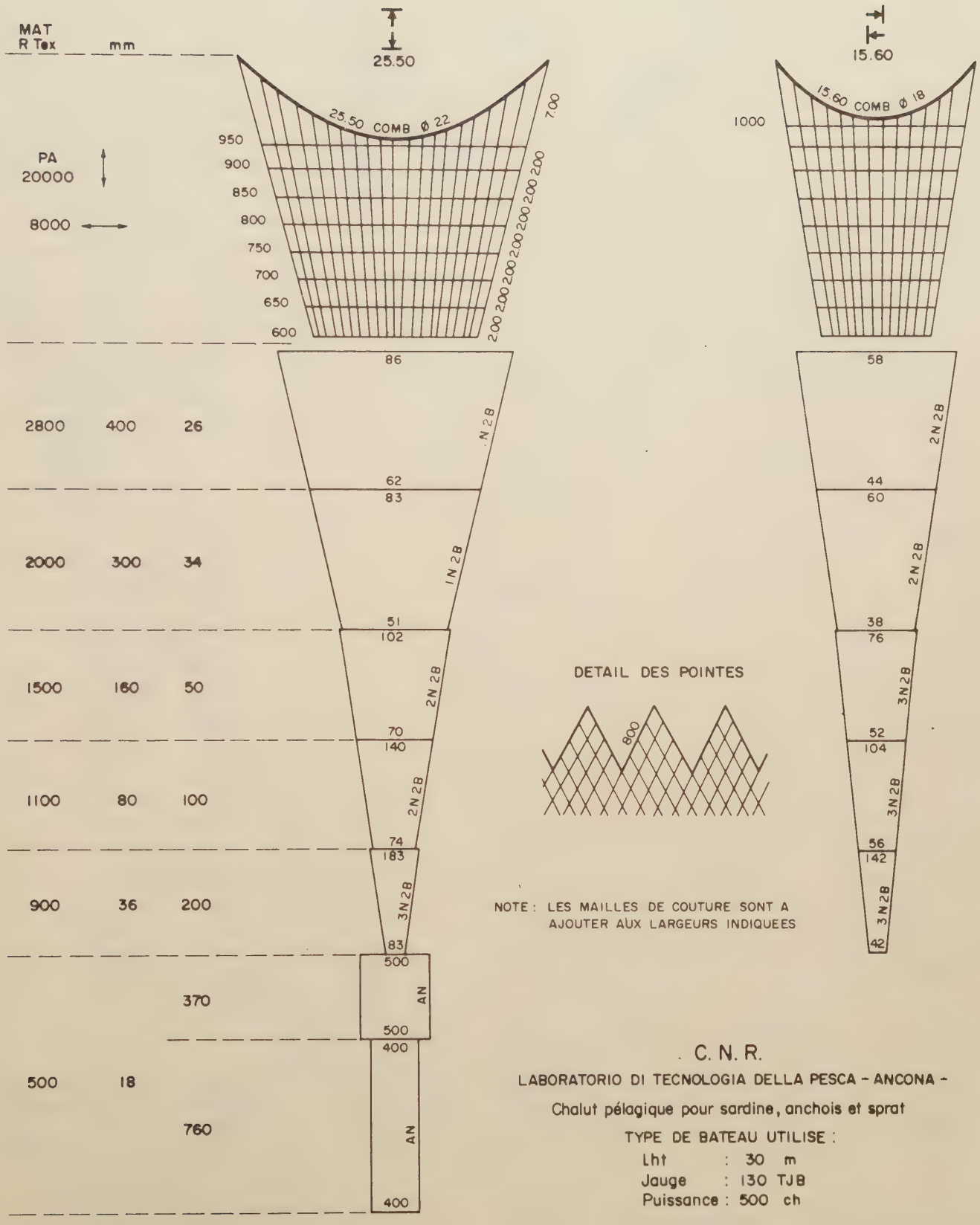
9. Comparisons with fisheries data and statistics

10. Research on aggregation structures and behaviour

11. Acoustic research

However, only if the survey data are collected in a standard and statistically correct way, can the potential users utilize these data and obtain effective benefits.

Annex(e) D



C. N. R.

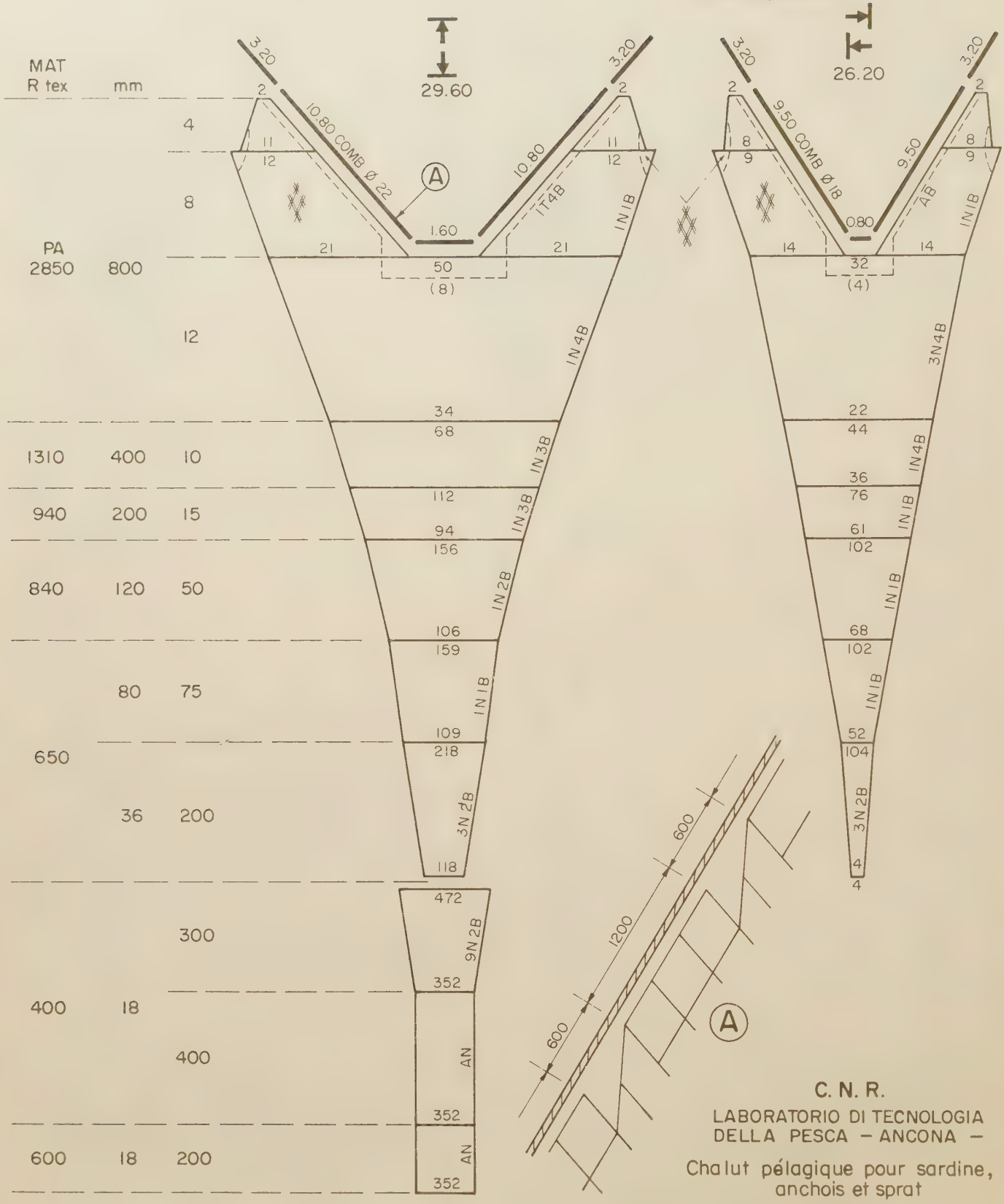
LABORATORIO DI TECNOLOGIA DELLA PESCA - ANCONA -

Chalut pélagique pour sardine, anchois et sprat

TYPE DE BATEAU UTILISE :

Lht : 30 m
Jauge : 130 TJB
Puissance : 500 ch

Annex(e) D
cont'd/suite



NOTE : LES MAILLES DE COUTURE SONT A AJOUTER AUX LARGEURS INDIQUEES

C. N. R.
LABORATORIO DI TECNOLOGIA DELLA PESCA – ANCONA –

Chalut pélagique pour sardine, anchois et sprat

TYPE DE BATEAU UTILISE :

Lht : 20 - 25 m
Jauge : 80 - 100 TJB
Puissance : 250 - 300 ch

THE ACCURACY OF ECHO SURVEYS

A: INTERNAL FACTORS OF TECHNICAL NATURE

1:

1.1 Beam position and T.V.G. (time varied gain) effect

- a) Depth location of the transducer
- b) The feature of the T.V.G. function of the receiving system
- c) Beam shape and pulse length employed plus topography of the sea bed

1.2 Noise field effect

- a) Intensity of the noise field radiated by a moving vessel
- b) Vulnerability of the fish species and hence reaction to the noise

1.3 Measuring device effect

- a) Accuracy of electro-acoustic measuring device
- b) Occasional uncertainty in assigning echo returns to known fish species

1.4 Other causes

- a) Level of stabilization of moving research boat (equipment)
- b) Operators skill to optimize control settings

2:

2.1 The effective sonar range problem

2.2 Sample window effect

B: SEMI-INTERNAL FACTORS OF TECHNICAL NATURE

1:

Accuracy with which system calibrations can be performed

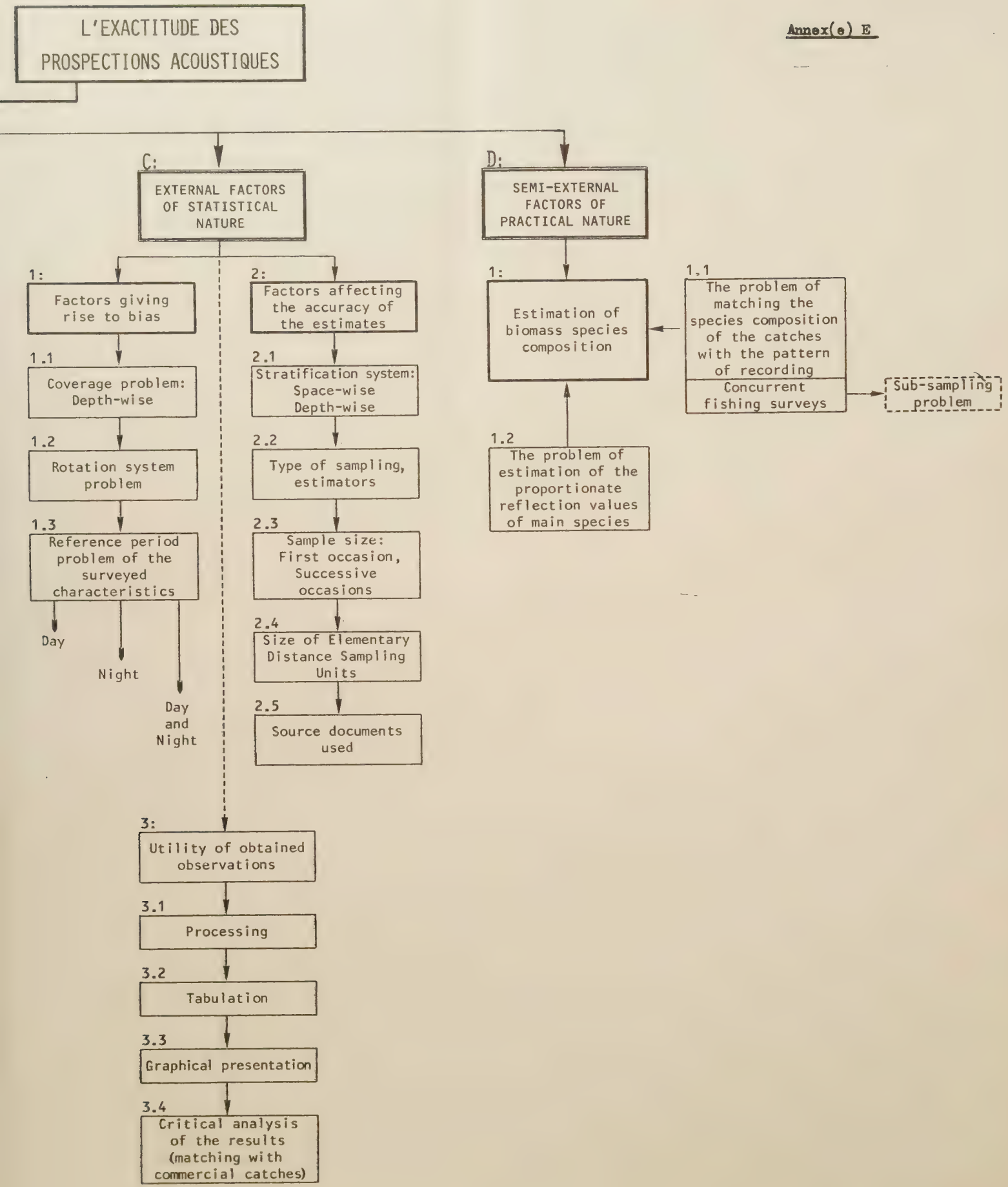
Level of reliability of estimated calibration coefficient

2:

Accuracy of methods with which school sizes are estimated

- Shape
- Dimensions
- Packing density

Annex(e) E


L'EXACTITUDE DES PROSPECTIONS ACOUSTIQUES
C:
EXTERNAL FACTORS OF STATISTICAL NATURE
D:
SEMI-EXTERNAL FACTORS OF PRACTICAL NATURE
1:
Factors giving rise to bias
1.1
Coverage problem: Depth-wise
1.2
Rotation system problem
1.3
Reference period problem of the surveyed characteristics
Day
Night
Day and Night
2:
Factors affecting the accuracy of the estimates
2.1
Stratification system: Space-wise Depth-wise
2.2
Type of sampling, estimators
2.3
Sample size: First occasion, Successive occasions
2.4
Size of Elementary Distance Sampling Units
2.5
Source documents used
3:
Utility of obtained observations
3.1
Processing
3.2
Tabulation
3.3
Graphical presentation
3.4
Critical analysis of the results (matching with commercial catches)
1:
Estimation of biomass species composition
1.1
The problem of matching the species composition of the catches with the pattern of recording
Concurrent fishing surveys
Sub-sampling problem
1.2
The problem of estimation of the proportionate reflection values of main species

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